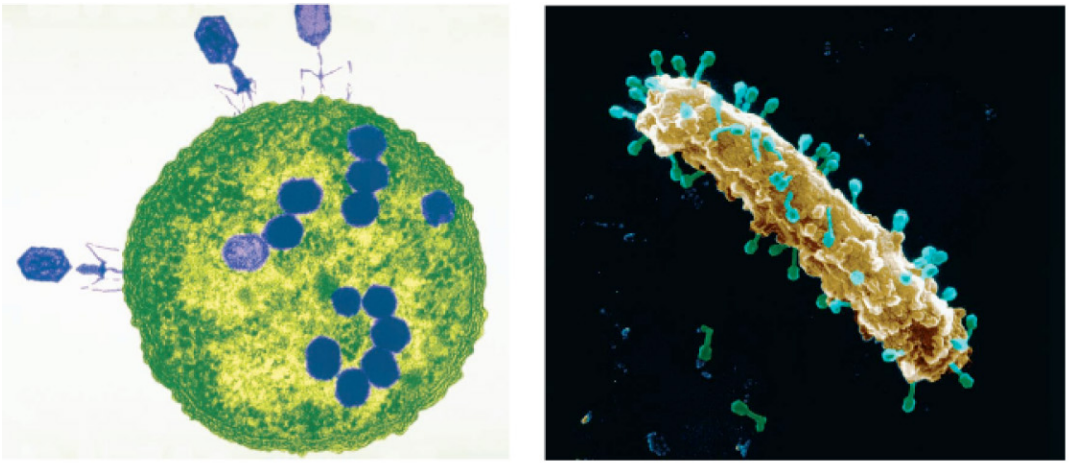

(a) (b)

FIGURE 27–15 Electron micrographs (in false color) of viruses attacking a cell of the bacterium *Escherichia coli*: (a) transmission electron micrograph (≈50,000×); (b) scanning electron micrograph (≈35,000×).

The **scanning tunneling electron microscope** (STM), developed in the 1980s, contains a tiny probe, whose tip may be only two or three atoms wide, that is moved across the specimen to be examined in a series of linear passes, like those made by the electron beam in a TV tube (CRT, Section 17–10). The tip, as it scans, remains very close to the surface of the specimen, about 1 nm above it, Fig. 27–16. A small voltage applied between the probe and the surface causes electrons to leave the surface and pass through the vacuum to the probe, by a process known as *tunneling* (discussed in Section 30–12). This "tunneling" current is very sensitive to the gap width, so a feedback mechanism can be used to raise and lower the probe to maintain a constant electron current. The probe's vertical motion, following the surface of the specimen, is then plotted as a function of position, producing a three-dimensional image of the surface. Surface features as fine as the size of an atom can be resolved: a resolution better than 0.1 nm laterally and 0.01 nm or better vertically. This kind of resolution has given a great impetus to the study of the surface structure of materials. The "topographic" image of a surface actually represents the distribution of electron charge.

The **atomic force microscope** (AFM), developed in the 1980s, is in many ways similar to an STM, but can be used on a wider range of sample materials. Instead of detecting an electric current, the AFM measures the force between a cantilevered tip and the sample, a force which depends strongly on the tip-sample separation at each point. The tip is moved as for the STM.

PHYSICS APPLIED

STM and AFM

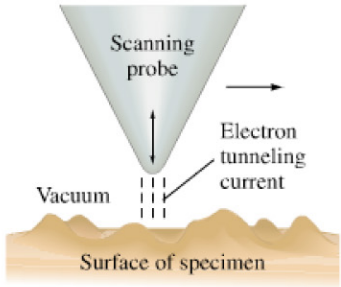

FIGURE 27–16 Probe tip of scanning tunneling electron microscope moves up and down to maintain constant tunneling current. A plot of the probe's motion produces an image of the surface.

27–10 Early Models of the Atom

The idea that matter is made up of atoms was accepted by most scientists by 1900. With the discovery of the electron in the 1890s, scientists began to think of the atom itself as having a structure with electrons as part of that structure. We now introduce our modern approach to the atom and the quantum theory with which it is intertwined.†

†Some readers may say: "Tell us the facts as we know them today, and don't bother us with the historical background and its outmoded theories." Such an approach would ignore the creative aspect of science and thus give a false impression of how science develops. Moreover, it is not really possible to understand today's view of the atom without insight into the concepts that led to it.